



IPCS INTERNATIONAL PROGRAMME ON CHEMICAL SAFETY
Health and Safety Guide No. 102

THALLIUM AND THALLIUM COMPOUNDS
HEALTH AND SAFETY GUIDE

UNITED NATIONS ENVIRONMENT PROGRAMME

INTERNATIONAL LABOUR ORGANISATION

WORLD HEALTH ORGANIZATION

WORLD HEALTH ORGANIZATION, GENEVA 1996

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WHO Library Cataloguing in Publication Data

Thallium and thallium compounds: health and safety guide.

(Health and safety guide ; no. 102)

1. Thallium - toxicity I. Series

ISBN 92 4 151102 8

(NLM Classification: QV 618)

ISSN 0259-7268

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ADMIN RECORD

SW-A-006016

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INTRODUCTION

The Environmental Health Criteria (EHC) monographs produced by the International Programme on Chemical Safety include an assessment of the effects on the environment and on human health of exposure to a chemical or combination of chemicals, or physical or biological agents. They also provide guidelines for setting exposure limits.

The purpose of a Health and Safety Guide is to facilitate the application of these guidelines in national chemical safety programmes. The first three sections of a Health and Safety Guide highlight the relevant technical information in the corresponding EHC. Section 4 includes advice on preventive and protective measures and emergency action; health workers should be thoroughly familiar with the medical information to ensure that they can act efficiently in an emergency. Within the Guide is a Summary of Chemical Safety Information which should be readily available, and should be clearly

explained, to all who could come into contact with the chemical. The section on regulatory information has been extracted from the legal file of the International Register of Potentially Toxic Chemicals (IRPTC) and from other United Nations sources.

The target readership includes occupational health services, those in ministries, governmental agencies, industry, and trade unions who are involved in the safe use of chemicals and the avoidance of environmental health hazards, and those wanting more information on this topic. An attempt has been made to use only terms that will be familiar to the intended user. However, sections 1 and 2 inevitably contain some technical terms. A bibliography has been included for readers who require further background information.

Revision of the information in this Guide will take place in due course, and the eventual aim is to use standardized terminology. Comments on any difficulties encountered in using the Guide would be very helpful and should be addressed to:

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THE INFORMATION IN THIS GUIDE SHOULD BE CONSIDERED AS A STARTING POINT TO A COMPREHENSIVE HEALTH AND SAFETY PROGRAMME

1. PRODUCT IDENTITY AND USES

1.1 Identity

The chemical names, chemical formula and CAS numbers of thallium and of some thallium compounds are given in Table 1.

1.2 Physical and Chemical Properties

Thallium is a soft and malleable heavy metal with a bluish-white colour. Its relative molecular mass is 204.283. Its most important compound is the colourless odourless and tasteless thallium(I) sulfate, previously used on a large scale as a rodenticide. Monovalent (thallous) compounds behave like, and may be as reactive as, alkali metals, e.g., potassium, whereas the trivalent (thallic) compounds are less basic, resembling aluminium.

Some physical properties are summarized in Table 1.

1.3 Analysis

Since concentrations of thallium in environmental samples are normally very low, determination directly from the sample or from the digestion solution usually lacks sufficient accuracy. Therefore, preconcentration procedures are necessary. For the $\mu\text{g/kg}$ range or less, isotope dilution and inductively coupled plasma mass spectrometry coupled with electrothermal vaporization or graphite furnace atomic absorption spectrometry are used. Usually the limit of detection for the latter is in the range of 0.6-20 $\mu\text{g/kg}$.

1.4 Production and Uses

Thallium is produced industrially only in small quantities (in 1987 and 1988 worldwide production was about 17 tonnes; in 1991 world-wide industrial consumption was 10 to 15 tonnes). However, each year nearly 1000 tonnes of thallium are released into the environment, mainly from mineral smelters, coal-burning power plants, brickworks and cement plants.

Thallium has a wide variety of industrial uses. Its use as a depilatory for humans or as a rodenticide and insecticide has now been prohibited or severely reduced. Thallium is now mainly used in the electrical and electronic industries and in the production of special glasses. Another important field of application is the use of radioisotopes in medicine for scintigraphy and the diagnosis of melanoma.

TABLE 1 PHYSICAL AND CHEMICAL PROPERTIES OF THALLIUM AND SOME SELECTED THAL

Name	Chemical formula	CAS registry number	Relative atomic/molecular mass	Specific gravity (g/cm ³)	
Thallium	Tl	7440-28-0	204.38	11.85	
Thallium(I) acetate	TlC ₂ H ₃ O ₂	563-68-8	263.43	3.765	1
Thallium aluminium sulfate	TlAl(SO ₄) ₂ *12 H ₂ O	52238-56-9	639.66	2.306	9
Thallium(I) bromide	TlBr	7789-40-0	284.29	7.557 (17.3°C)	
Thallium(I) carbonate	Tl ₂ CO ₃	29809-42-5	468.78	7.110	2
Thallium(I) chloride	TlCl	7791-12-0	239.84	7.004 (30°C)	
Thallium(III) trichloride	TlCl ₃	13453-32-2	310.74	-	11
	TlCl ₃ *4H ₂ O	13453-33-3	382.80	-	12
Thallium ethylate	TlOC ₂ H ₅	20398-06-5	249.44	3.493 (20°C)	
Thallium(I) fluoride	TlF	7789-27-7	223.38	8.23 (4°C)	

TABLE 1 (Con't)

Name	Chemical formula	CAS registry number	Relative atomic/molecular mass	Specific gravity (g/cm ³)
Thallium(III) trifluoride	TlF ₃	7783-57-5	261.38	8.36 (25°C)
Thallium hydroxide	TlOH	1310-83-4	221.39	-
Thallium(I) iodide (alpha)	TlI	7790-30-9	331.29	7.29
Thallium(I) nitrate (alpha)	TlNO ₃	10102-45-1	266.39	-
Thallium (III) nitrate decomposes trihydrate	Tl(NO ₃) ₃ ·3H ₂ O	13453-38-8	444.44	-
Thallium(I) oxide	Tl ₂ O	1314-12-1	424.77	9.52 (16°C)
Thallium(III) oxide	Tl ₂ O ₃	1314-32-5	456.76	10.19 (22°C)
Thallium(I) sulfate	Tl ₂ SO ₄	7446-18-6	504.82	6.77
Thallium(I) sulfide	Tl ₂ S	1314-97-2	440.85	8.46

^a From: Stokinger (1987); Budavari (1989); Lide (1990)

2. SUMMARY AND EVALUATION

2.1 Environmental transport, distribution and transformation

Near point sources such as coal-fired power-generating stations, some cement plants and metal smelting operations, the major source of thallium in air is emission of fly ash. The results of one study indicate that nearly all of the thallium in fly dust from a cement plant was present as soluble thallium(I) chloride.

The fate of thallium added to soil (in deposited fly ash, for example) depends largely on soil type. Retention will be greatest in soils that contain large amounts of clay, organic matter and iron/manganese oxides. Incorporation into stable complexes causes enhanced thallium concentrations only in the upper levels of soils. The uptake of thallium by vegetation increases as soil pH decreases. In some strongly acid soils significant amounts of thallium can be leached to local ground and surface water.

Most dissolved thallium in freshwater is expected to be in the

monovalent form. However, in strongly oxidized fresh water and most seawater trivalent thallium may predominate. Thallium can be removed from the water column and accumulate in sediment by various exchange, complexation or precipitation reactions.

Although thallium can bioconcentrate, it is not likely to biomagnify in aquatic or terrestrial food webs.

2.2 Environmental levels and human exposure

In areas not contaminated by thallium, concentrations in air are usually $< 1 \text{ ng/m}^3$, those in water $< 1 \text{ }\mu\text{g/litre}$, and those in water sediments $< 1 \text{ mg/kg}$. Mean concentrations in the earth's crust range from 0.1 to 1.7 mg/kg, but very high concentrations are possible, e.g., in coal up to 1000 mg/kg, and the rarely found minerals of thallium consist of up to 60% of the element. Food of plant and animal origin usually contains $< 1 \text{ mg/kg}$ dry weight and the human average dietary intake of thallium appears to be less than $5 \text{ }\mu\text{g/day}$. Uptake via the respiratory system is estimated to be $< 0.005 \text{ }\mu\text{g thallium/day}$.

There are only limited data about the actual thallium content of workplace air. The most recent (1980s) concentrations of thallium observed were $< 22 \text{ }\mu\text{g thallium/m}^3$ (in the production of a special thallium alloy and in a thallium smelter). Average urinary concentrations were determined to be in the range of $0.3\text{--}8 \text{ }\mu\text{g/litre}$ for cement workers and $0.3\text{--}10.5 \text{ }\mu\text{g/litre}$ for foundry workers.

2.3 Kinetics and metabolism in laboratory animals and humans

Thallium is rapidly and well absorbed through the gastrointestinal and respiratory tracts and is also taken up through the skin. It is rapidly distributed to all organs and passes the placenta (as indicated by the rapid fetal uptake) and the blood-brain barrier. Because of its rapid accumulation in cells, concentrations of thallium in whole blood do not reflect the levels in tissues. In acute poisoning of experimental animals or humans, initially high concentrations of thallium appear in the kidney, low concentrations in fat tissue and brain, and intermediate concentrations in the other organs; later the thallium concentration of the brain also increases.

Elimination of thallium may occur through the gastrointestinal tract (mainly by mechanisms independent of biliary excretion), kidney, hair, skin, sweat and breast milk. Intestinal reabsorption (mainly from the colon) may occur with a consequent decrease in total body clearance. In rats, the main routes of thallium elimination are gastrointestinal (about two thirds) and renal (about one third), in rabbits the contribution of the two routes is about equal. Thallium is also secreted in saliva.

As with many other substances, the excretion of thallium in humans differs from that in laboratory animals, since the rate of excretion is generally much lower in humans (rate constant = $0.023\text{--}0.069 \text{ day}^{-1}$) than in laboratory animals (average rate constant = 0.18 day^{-1}). Another major difference between humans and animals is the relative contribution of the different routes of excretion. In humans, renal excretion seems to be much more important than in animals, although its relative contribution to the total body clearance has not been definitively established, due principally to the lack of sufficient human data. Moreover, exposure levels,

duration of exposure, impairment of excretory organ function, potassium intake and concomitant treatment of acute poisoning may considerably influence the results.

In one study renal excretion of thallium was reported to be about 73%, whereas that through the gastrointestinal tract was about 3.7% of the daily excreted amount. Excretion through hair and skin, and sweat has been estimated to be 19.5% and 3.7%, respectively.

The biological half-life of thallium in laboratory animals generally ranges from 3 to 8 days; in humans it is about 10 days but values up to 30 days have been reported.

No data on the biotransformation of thallium are available.

2.4 Effects on laboratory mammals and in vitro test systems

There are no striking species-specific differences in the toxicity of thallium(I) salts. Usually an oral intake of 20 to 60 mg thallium/kg body weight is lethal within one week. Guinea-pigs are slightly more sensitive than other experimental animals. The water-insoluble thallium(III) oxide shows a somewhat lower acute toxicity by oral or parenteral administration than thallium(I) salts. Comparison of acute toxicity data indicates a high degree of bioavailability from all exposure routes. Most organs are affected, but the signs of poisoning and the sequence in which they occur reveal some intra- and interspecies variability.

The symptoms of acute intoxication generally follow the following sequence: firstly anorexia, vomiting and depression, later diarrhoea, skin changes (inflammation at body orifices, skin furuncles, hair loss), and then dyspnoea and nervous disorders. Finally, respiratory failure leads to death.

Symptoms of chronic intoxication are similar to those of acute intoxication. Loss of hair regularly occurs.

Histological examination reveals necrosis or other cell damage. Necrotic changes have been observed in the kidneys, liver, intestine, heart and the nervous system. Swelling of mitochondria and loss of cristae, dilatations of smooth endoplasmic reticulum, increased numbers of autophagic vacuoles and lipofuscin granules, and loss of microvilli have been observed in many cells. The thallium-induced alterations of functional processes may arise from physical disruption of the membranes of subcellular organelles. In the heart, arrhythmogenic effects are restricted to the sinus node.

Thallium intoxication causes selective impairment of certain behavioural elements, which are correlated with biochemical effects (which indicate cellular damage) in certain regions of the brain. Some neurological effects seem to be caused by direct action, e.g. ataxia and tremor by cerebellar alterations or alterations in endocrine activity through changes in the hypothalamus. The autonomic nervous system, mainly the adrenergic, may be activated by thallium. In peripheral nerves, thallium seems to interfere presynaptically, with the spontaneous release of transmitter, by antagonizing these calcium-dependent processes.

The exact mechanism of thallium toxicity is still unknown. Several, perhaps interconnected, mechanisms have been postulated. An

important aspect of thallium intoxication is the significant increase in lipid peroxidation and in the activity of the lysosomal enzyme β -galactosidase. The resulting deficiency of glutathione leads to the

accumulation of lipid peroxides in the brain and, presumably, finally to lipofuscin granules. The mode of action of thallium seems to be mainly due to a disturbance of the function of the mitochondria.

Sexual activity is usually reduced in chronically poisoned animals, and gonadotoxic effects of thallium are evident in the male reproductive system. In the testes of rats given 10 mg thallium/litre in the drinking-water for 16 days, the Sertoli cells were most sensitive, and desquamation of the spermatogenic epithelium led to immature sperm cells in the semen. This could explain the decreased survival rate of embryos or reduced life span of offspring after sublethal thallium-poisoning of the fathers.

Teratogenic effects, growth inhibition and disturbances in the development of bones were found to occur in chicken embryos after injection of thallium into the egg, but such effects in mammals, even at maternotoxic doses, are controversial. Although transplacental transfer has been demonstrated, many strains of mice and rats show no or only slight teratogenic effects.

Two microbiological mutagenicity tests in *Salmonella typhimurium* were negative and *in vivo* tests on sister chromatid exchange were controversial. However, single studies report chromosomal aberrations or a significant increase of single-stranded DNA breaks.

Long-term studies on the carcinogenicity of thallium are lacking.

2.5 Effects on humans

Since thallium salts are tasteless, odourless, colourless, highly toxic, were easily obtainable in the past and still are in some developing countries, thallium has often been used for suicide, homicide and attempts at illegal abortion, causing acute thallium poisoning. Indeed, thallium intoxication is considered one of the most frequent causes, on a worldwide scale, of purposeful or accidental human poisoning. Knowledge of chronic thallium intoxication is limited to occupational exposure, to population groups in contaminated areas and to cases of homicide involving multiple low doses.

Symptoms of acute thallium toxicity depend on age, route of administration and dose. Doses which have proved lethal vary between 6 and 40 mg/kg, being on average 10 to 15 mg/kg. Without therapy this average dose usually results in death within 10 to 12 days, but death occurring within 8-10 h has also been reported.

The triad of gastroenteritis, polyneuropathy and alopecia is regarded as the classic syndrome of thallium poisoning, but in some cases gastroenteritis and alopecia were not observed. Several other signs and symptoms also occur, varying in order, extent and intensity.

Symptoms of thallium intoxication are often diffuse and initially include anorexia, nausea, vomiting, metallic taste, salivation, retrosternal and abdominal pain and occasionally gastrointestinal haemorrhage (blood in faeces). Later, constipation is commonly seen and may be resistant to treatment, thus interfering with antidotal

treatment.

After 2 to 5 days some of the typical thallium disorders slowly develop, irrespective of the route of exposure. Effects on the central and peripheral nervous system vary, but a consistent and characteristic feature of thallium intoxication in humans is the extreme sensitivity of the legs, followed by the "burning feet syndrome" and paraesthesia. Involvement of the central nervous system (CNS) is indicated by symptoms like hallucinations, lethargy, delirium, convulsions and coma. Common circulatory symptoms are hypertension, tachycardia and, in severe cases, cardiac failure. Loss of head hair and sometimes body hair occurs after the second week of poisoning; dystrophy of the nails is manifested by the appearance of white lunular stripes (Mee's lines) 3 to 4 weeks after intoxication. The black regions found in hair papillae are not caused by deposition of pigments or thallium but are due to small amounts of air entering the shaft.

In lethal cases the time until death occurs may vary from hours to several weeks, but most commonly death occurs within 10 to 12 days. Causes of death are mainly renal, CNS and cardiac failure.

In sublethal poisonings, recovery often requires months. Sometimes neurological and mental disturbances as well as electroencephalographic abnormalities and blindness can remain. Additionally, intellectual functions seem to be adversely affected in survivors.

In cases of chronic poisoning, symptoms are similar but in general milder than in cases of acute intoxication. Sometimes permanent blindness occurs. Complete recovery takes months and can be interrupted by relapses.

In a well-investigated case of thallium emission around a cement plant in Lengerich, Germany, thallium concentrations in the hair and urine of exposed people did not correlate with certain features which are known to be usually associated with chronic thallium poisoning, but only with subjective neurological symptoms.

Postmortem examinations or biopsies following thallium poisoning reveal damage of various organs. For example, after ingestion of lethal doses, haemorrhages in the mucosa of the intestine, lung, endocrine glands and heart, fatty infiltrations in liver and heart tissue, and degenerative changes to glomeruli and renal tubules occur. In the brain, fatty degeneration of ganglion cells, damage to axons and disintegration of myelin sheaths can be observed.

Variations in blood pressure may be caused by direct effects of thallium on the autonomic nervous system. Thallium intoxication causes symmetric, mixed peripheral neuropathy. Distal nerves are affected more than proximal nerves, and earlier but lesser degrees of damage occur in nerves with shorter axons, e.g., cranial nerves. Axons are swollen and contain vacuoles and distended mitochondria. In lethal poisoning, severe damage of the vagus nerve, denervation of the carotid sinus and lesions of the sympathetic ganglia have been observed. In sublethal poisoning, affected nerves may undergo axonal degeneration with no or only partial recovery within 2 years.

Retrobulbar neuritis and resulting visual disorders can develop and persist for months after terminating treatment with thallium-

containing depilatories, and even optic atrophy may occur.

Limited data are available on the effects of thallium on human reproduction. Menstrual cycle, libido and male potency may be adversely affected. Effects on sperm are known to occur following chronic intoxication. As in animal studies, transplacental transfer occurs; this was seen following a thallium-induced abortion. However, apart from a relatively low weight and alopecia of newborn babies, fetal development was not affected in about 20 cases of thallium intoxication during pregnancy.

No reports of any carcinogenic effects or data on immunological effects of thallium are available. There is no adequate evidence of genotoxic effects.

Therapies of thallium intoxication combine forced diuresis, use of activated charcoal and prevention of re-absorption in the colon by administration of Prussian blue, potassium ferric hexacyanoferrate(II).

2.6 Human dose-response relationship

The mean urinary thallium concentration in unexposed populations is 0.3 to 0.4 $\mu\text{g/litre}$. As thallium has a short biological half-life, measured in days, and assuming steady-state conditions, this urinary concentration can be taken as an indicator of total dose following inhalation and dietary intake.

The mean urinary thallium concentration in a population sample living near a thallium atmospheric emission source was 5.2 $\mu\text{g/litre}$. A clear dose-response relationship was found between urinary thallium concentration and the prevalence of tiredness, weakness, sleep disorders, headache, nervousness, paraesthesia, and muscle and joint pain. A similar dose-response relationship was also reported when thallium in hair was used as an indicator of exposure.

The Task Group considered that exposures causing urinary thallium concentrations below 5 $\mu\text{g/litre}$ are unlikely to cause adverse health effects. In the range of 5-500 $\mu\text{g/litre}$ the magnitude of risk and severity of adverse effects are uncertain, while exposure giving values over 500 $\mu\text{g/litre}$ have been associated with clinical poisoning.

2.7 Effects on other organisms in the laboratory and field

Thallium affects all organisms, but species- and also strain-specific differences are evident. Different inorganic thallium(I) and thallium(III) compounds and organothallium compounds can show different toxicities.

The most important effect of thallium on microorganisms seems to be inhibition of nitrification by soil bacteria. Results of one study suggest that microbial community structure is disturbed at soil concentrations in the range of 1-10 mg/kg dry weight, but the form of thallium used in this experiment was not identified.

Thallium is taken up by all plant parts, but principally by the roots. After uptake into the cell, it is concentrated unevenly in the cytosol, probably bound to a peptide. Thallium concentrations found in plants depend on soil properties (especially pH, clay and organic matter content), as well as on the developmental stage and on the part

of the plant. Thallium accumulates in chlorophyll-containing regions, but to a lesser degree in thallium-resistant plants. Oxygen production is reduced by thallium, presumably by direct action on electron transfer in photosystem II. Interference with the pigments is indicated by the occurrence of chlorosis. In addition, impaired uptake of trace elements seems to be involved in the mechanism of toxicity. Growth is also affected, roots reacting more sensitively than leaves or stems. These effects have been reported at concentrations as low as 1 mg thallium/kg of dry plant tissue, after exposure to monovalent forms of thallium.

Most studies of effects on aquatic organisms have used soluble monovalent thallium compounds. The lowest thallium concentration reported to affect aquatic species is 8 µg/litre, which caused a reduction in growth of aquatic plants. Invertebrates are often

affected at lower concentration than fish (96-h LC₅₀ values are 2.2 mg thallium/litre for daphnids and 120 mg/litre for a freshwater fish). The lowest LC₅₀ value, reported after exposure for about 40 days, was 40 µg/litre for fish.

Many cases of thallium intoxication of wildlife have been caused by its large scale application as a rodenticide. In seed-eating animals and predators the CNS and/or the gastrointestinal tract are most severely affected. These effects can also be observed in farm animals. In addition, thallium causes a loss of dorsal feathers in ducks, salivation from the nose and mouth of cattle, and reduced growth in broilers, laying hens, sheep and steers.

3. CONCLUSIONS AND RECOMMENDATIONS

Thallium is currently produced and used industrially in only small quantities. However, metal mixing and smelting operations, as well as cement plants using thallium-containing pyrite, can release significant amounts of thallium. Stack gases and wastewater should be monitored and, if necessary, controlled. Measures should be taken to reduce occupational exposure (e.g., protective clothing should be worn, dust scattering should be avoided).

Environmental exposure to thallium does not pose a health threat for the general population. The total intake has been estimated to be less than 5 µg/day, the vast majority coming from food. Drinking-water and air generally contribute only very small amounts of thallium.

Exposures should be kept to levels that lead to urinary concentrations of less than 5 µg/litre, which corresponds to a daily oral intake of approximately 10 µg thallium.

Where thallium is still available for use as a rodenticide, the potential for poisoning remains a significant concern. Thallium should no longer be used for this purpose, particularly as less hazardous methods of rodent control are available.

4. HUMAN HEALTH HAZARDS, PREVENTION AND PROTECTION, EMERGENCY ACTION

~~4.1 Human Health Hazards, Prevention and Protection, First Aid~~

Since all thallium compounds are toxic and since thallium is rapidly absorbed through all exposed epithelia, it is essential that

the correct precautions should be observed during handling and use.

4.1.1 Advice to physicians

4.1.1.1 Signs and symptoms of exposure

In acute thallium poisoning the onset of symptoms is often insidious, reaching a maximum in the second or third week after exposure. The initial clinical features include a gradual development of gastrointestinal disturbance (severe constipation), hyperaesthesia, paraesthesia, hyperalgesia of the lower limbs (affecting especially the soles of the foot), followed by motor weakness of the lower limbs and foot drop. Encephalopathy and retrobulbar neuritis occur in severe poisoning. At the end of the second week, the characteristic symptom of hair loss appears. Development of psychiatric disturbances ranging from hysterical behaviour to complete psychosis may be observed. In severe poisoning the patient may die early of myocardial failure.

4.1.1.2 First aid

Medical care and hospital treatment is necessary as soon as possible. Contaminated skin should be flushed with water and washed with soap and water. If the eyes are splashed with thallium-containing liquids they should be flushed immediately with clean water for at least 15 min. In the event of ingestion, vomiting should be induced in conscious patients and followed by gastric aspiration and lavage. Charcoal haemoperfusion has been shown to be successful if used within 48 h of thallium ingestion but this should be restricted to intoxications with high doses of thallium.

4.1.1.3 Medical treatment

Forced diuresis (8-12 litres/day) may be used until the urinary excretion rate is < 1 mg thallium/24 h (beware of heart failure due to impairment of the pacemaker function of the heart and myocardial contractility).

A very effective oral antidote is Prussian Blue, potassium ferric hexacyanoferrate(II), an inorganic pigment which is not absorbed by the gut. Potassium ions in the molecule are exchanged for thallium ions. Thus, absorption in the intestine is prevented and the thallium-loaded molecule is excreted with the faeces. This therapy results in faecal elimination greatly exceeding urinary elimination.

Two 10 g doses of Prussian Blue should be given daily (preferably intraduodenally in 100 mg 15% mannitol as a laxative) until urinary thallium excretion is < 0.5 mg/24 h. Daily defecation is necessary.

4.1.2 Health surveillance advice

People suffering from renal or hepatic disease, anaemia, blood dyscrasias, hypertension, alcoholism, chronic infections or endocrine gland dysfunction should be excluded from working with thallium.

The urinary thallium concentration of people exposed occupationally should be determined periodically in a programme of biological monitoring. The intervals between monitoring should depend on the degree of exposure. Periodic examinations should pay particular attention to the typical effects of thallium, e.g., kidney

and eye function, the presence of pain in the limbs and hair loss.

4.1.3 Prevention and protection

Recommendations for the protection of employees in industrial plants using thallium fall under three headings:

4.1.3.1 General recommendations

Access to rooms in which thallium is used should be restricted to a limited number of employees. Employees should be repeatedly informed about risk and industrial hygiene, as applies to employees working with radioisotopes. They should be instructed to report any unusual health symptoms. Employees should be encouraged to eat potassium-rich food, e.g., bananas.

4.1.3.2 Engineering control

Dust scattering should be avoided and handling of thallium should be carried out under a hood. Dust should be controlled within the recommended threshold limit value of 0.1 mg/m^3 . Floors and tables should be wet-mopped. Dust samplers should be installed for the determination of thallium concentrations in the air.

4.1.3.4 Personal protective equipment and hygienic measures

Employees should be required to use protective workclothes, including gloves. The complete set of personal work clothes should be kept separate from normal clothes. They should be washed at least once a week. Clothes should be changed before eating, drinking or smoking, which should all be prohibited at the working place. Washing and showering facilities should be provided and their use encouraged. Individual respirators should be worn in all operations producing dust or fumes.

4.2 Explosion and Fire Hazards

Finely dispersed thallium particles can form explosive mixtures in air. However, thallium compounds do not present an explosion risk, nor are they flammable. Only thallium(III) nitrate trihydrate ($\text{Tl}(\text{NO}_3)_3 \cdot 3\text{H}_2\text{O}$) is classified as a fire supporting agent and so contact with flammable compounds should be avoided.

4.3 Storage

All products should be stored in secure buildings, kept dry and out of the reach of children and animals, and separated from food, drinks and animal feed.

Thallium should be stored in a fireproof location, separate from strong oxidants, strong acids, fluorine and oxygen, and kept under vasoline oil.

4.4 Transport

For transport unbreakable packaging should be used or breakable packaging should be put into unbreakable containers. Transporters should comply with national and international requirements regarding the transport of hazardous materials.

4.5 Spillage

The danger area should be evacuated and an expert be consulted. The spilled substance should be swept up and placed into containers. Extra personal protection is required, i.e. complete protective clothing including a self-contained breathing apparatus.

4.6 Disposal

Thallium(III) oxide can be precipitated with sodium hydroxide from aqueous solutions of thallium compounds.

5. HAZARDS FOR THE ENVIRONMENT AND THEIR PREVENTION

Thallium is not used on a large scale in industry, but emissions can pollute the environment around mineral smelters, coal-burning power plants, brickworks and cement plants using thallium-enriched pyrite. The emissions can be reduced by the use of raw material with low concentrations of thallium and by the exclusion of enrichment procedures. Waste slags should be marked and sealed to avoid leaching into soil and pollution from dust. The discharge of thallium from tailing ponds and emissions into the atmosphere should be reduced by adequate procedures.

Since thallium is incorporated into stable humus complexes, it remains for a long time in the upper layer of the soil. In regions with contaminated agricultural or garden soil, the thallium concentrations in the upper layer should be reduced by deep ploughing or by the addition of uncontaminated soil.

Thallium is toxic to aquatic organisms but effects are likely to be limited to sites adjacent to point sources. Although it can bioconcentrate, thallium is unlikely to biomagnify in aquatic or terrestrial food webs.

The use of thallium as a rodenticide has resulted in poisoning of non-target organisms, including foxes, badgers, martens, partridges, pheasants and eagles. Poisoning of domestic animals, such as dogs, cats, ducks and pigeons, has also been widely reported. Less hazardous methods or rodent control should be used.

6. SUMMARY OF CHEMICAL SAFETY INFORMATION

This summary should be easily available to all health workers concerned with, and users of, thallium. It should be displayed at, or near, entrances to areas where there is potential exposure to thallium and on processing equipment and containers. The summary should be translated into the appropriate language(s). All persons potentially exposed to the chemical should also have the instructions in the summary clearly explained.

Space is available for insertion of the National Occupational Exposure Limit, the address and telephone number of the National Poison Control Centre, and local trade names.

SUMMARY OF CHEMICAL SAFETY INFORMATION

PHYSICAL PROPERTIES

THALLIUM METAL

THALLOUS
SULFATE

OTHER CHAR

Relative atomic/molecular mass	204.4	504.8	Thallium
Melting point (°C)	304	632	Soft malle
Boiling point (°C)	1457	decomposes	halogens a
Water solubility (g/litre at 20°C)	insoluble	48.7	strong oxi
Relative density (water = 1)	11.9	6.77	moisture;
CAS No. 7440-28-0	7446-18-6		mixtures i
			inhalation
			to harmful
			Thallous s
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SUMMARY OF CHEMICALS SAFETY INFORMATION (continued)**HAZARD/SYMPTOM****PREVENTION AND PROTECTION**

GENERAL: Short-term exposure may result in effects on the nervous system and in death; effects may be delayed; long-term exposure may cause hair loss and have effects on vision, the liver, lungs, nervous system and kidneys; may cause birth defects, specifically skeletal deformation, low birth weight, and premature birth; danger of cumulative effects

Prevent any spillage dispersion of inhalation of dust or skin contact; women should avoid exposure

INHALATION: Nausea, vomiting, loss of hair, abdominal colic, pain in legs and chest, nervousness, irritability

Apply ventilation, local exhaust or protection

SKIN: May be absorbed, resulting in the same symptoms as following inhalation

Avoid skin contact; wear clean, imp clothing, gloves and shoes

EYES: May be absorbed; redness, pain, blurred vision (after exposure to thallium sulfate)

Wear safety goggles or eye protecti

INGESTION: Abdominal pain, constipation, diarrhoea, headache, nausea, vomiting, loss of vision, loss of hair, nervousness, irritability, tremor, delirium, convulsions, paralysis, coma (in the case of thallous sulfate)

Do not eat, drink, chew, or smoke d do not keep food in areas with pote exposure; change clothes before eat drinking or smoking

SUMMARY OF CHEMICALS SAFETY INFORMATION (continued)**HAZARD/SYMPTOM**

ENVIRONMENT: May be hazardous to aquatic and terrestrial organisms and to the soil microflora

PREVENTION AND PROTECTION

Contamination of water, soil and air should be avoided by proper methods of storage, transport, and waste disposal

SPILLAGE

Evacuate the area and consult an expert; sweep up spilled substance and place into containers; remove to safe place (extra personal protection required: complete protective clothing including self-contained breathing apparatus)

STORAGE

Store away from foodstuffs and separate from strong oxidants, strong acids, fluorine, oxygen; keep under vasoline oil in fire-proof and well-labelled room

SUMMARY OF CHEMICALS SAFETY INFORMATION (continued)**WASTE DISPOSAL**

Dilute thallium solutions may be buried in an approved dump or landfill where there is no risk of contamination of surface or groundwater; when possible, thallium should be recovered and returned to the suppliers; comply with any local legislation regarding disposal of toxic wastes

NATIONAL INFORMATION

National occupational exposure limits

National Poison Control Centre:

7. CURRENT REGULATIONS, GUIDELINES, AND STANDARDS

Most of the information given in this section has been extracted from the International Register of Potentially Toxic Chemicals (IRPTC) legal file. A full reference to the original national document from which the information was extracted can be obtained from IRPTC.

The reader should be aware that regulatory decisions about chemicals, taken in a certain country, can only be fully understood in the framework of the legislation of that country. Furthermore, the

regulations and guidelines of all countries are subject to change and should always be verified with appropriate regulatory authorities before application.

7.1 Previous Evaluations by International Bodies

A *Poisons Information Monograph* for thallium has been issued (IPCS, 1992).

On the basis of an acute oral LD₅₀ of 11 mg/kg, thallium sulfate has been classified in the *WHO Recommended Classification of Pesticides by Hazard* as "highly hazardous" (Class Ib).

International Chemical Safety Cards have been issued for thallium metal (no. 77) and for thallous sulfate (no. 336) (CEC/IPCS, 1990, 1991).

7.2 Exposure Limit Values

Some exposure limit values are given in the Current Regulations, Guidelines and Standards table

7.3 Specific restrictions

In the Czech Republic the presence of thallium or its compounds in cosmetics is prohibited. In the European Economic Community countries, no detectable quantities of thallium may be contained in colouring matter authorized for use in foodstuffs intended for human consumption.

The use of thallium as a rodenticide has been prohibited in many countries.

CURRENT REGULATIONS, GUIDELINES AND STANDARDS

Exposure Limit Values

Medium	Specification	Country	Exposure limit description
AIR	Occupational	Argentina	Maximum permissible concentration (M) - Time-weighted average (TWA)
		Canada	Threshold limit value (TLV) - Time-weighted average (TWA)
		Germany	Maximum worksite concentration (MAK) - Time-weighted average (TWA) - Short-term exposure limit (STEL)
		Mexico	Maximum limit (MXL) - Time-weighted average (TWA)
		United Kingdom	Occupational exposure standard (OES) - Time-weighted average (TWA)
		USA (ACGIH)	Threshold limit value (TLV)

- Time-weighted average (TWA)

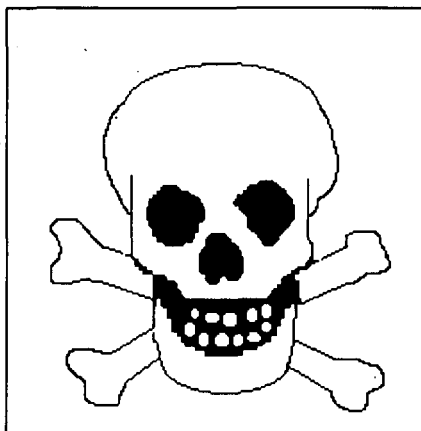
WATER	surface	Russian Federation	Maximum allowable concentration (MAC)
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7.4 Labelling, Packaging and Transport

The United Nations Committee of Experts on the Transport of Dangerous Goods and the International Maritime Organization classify thallium compounds as poisonous substances (Hazard Class 6.1) and, with regard to packing, as substances presenting medium danger (Packing Group II).

European Economic Community legislation requires labelling as a very toxic substance, using the symbol T+ and the following pictogram:

T+



VERY TOXIC

The following label statements are required for thallium

- R 26/28 Very toxic by inhalation and if swallowed
- R 33 Danger of cumulative effects
- S 2 Keep out of reach of children
- S 13 Keep away from food, drink and animal feeding stuffs
- S 28 After contact with skin, wash immediately with plenty of soap and water
- S 45 In case of accident or if you feel unwell, seek medical advice immediately (show label where possible)

For thallium sulfate the following label statements are required:

- R 28 Very toxic if swallowed
- R 38 Irritating to skin
- R 48/25 Toxic: danger of serious damage to health by prolonged

- exposure if swallowed
- S 13 Keep away from food, drink and animal feeding stuffs
- S 36/37 Wear suitable protective clothing and gloves.
- S 45 In case of accident or if you feel unwell, seek medical advice immediately (show the label where possible)

7.5 Waste Disposal

When possible, thallium should be recovered and returned to the suppliers. Dilute thallium solutions may be buried in an approved dump or landfill where there is no risk of contamination of surface or groundwater. Local legislation regarding disposal of toxic wastes must be complied with.

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See Also:

Toxicological Abbreviations